Combining Engineering and Engineering Technology Programs into a Single Capstone Design Sequence

D. Blake Stringer
Kent State University
dstring1@kent.edu

Maureen McFarland
Kent State University
mmcfarl2@kent.edu

Abstract

This paper describes the development of a two-course capstone sequence in aircraft design that specifically combines two programs: aerospace engineering and aeronautical systems engineering technology. It briefly summarizes the difference between an engineering and engineering technology curriculum and the suitability of each to the entire spectrum of engineering careers. It shows the combined lack of student exposure to engineering and engineering technology as a missed opportunity to enhance graduate preparedness to enter the workplace. It describes how the authors attempt to overcome this using a combined aerospace capstone sequence, which covers a variety of topics to include technical design, product development, process development, and non-technical aspects such as legal/regulatory and value proposition. Finally, it links the capstone to ABET outcomes, showing how the overall design experience meets these outcomes, while significantly enhancing the students' professional and technical skills. This strategy is still being implemented and will require 3-4 iterations to adequately assess the success of the sequence.

Introduction

The purpose of the capstone experience of any engineering technology and engineering (ETE) curricula is to combine all elements of the students' education into an integrative experience that exposes them to a complex problem-solving environment. This is the final milestone preparing students for entry into the workplace.

In many engineering curricula, the capstone takes the form of a comprehensive design project, as prescribed by ABET [1, 2]. The size and scope of the design can vary over a wide range of projects: paper designs, prototypes, design-build competitions, customer-specific, collaborative designs with industry, etc. All of these projects provide intrinsic value to the student and the capstone process.

An important developmental aspect of the capstone project is to develop the ability of students to work effectively on teams. Due to the nature of curriculum requirements, in many cases, the teams consist of other engineering students, either from the same discipline or a closely-related one. The relative lack of diversity is an unrealistic simulation of the workplace environment and can be a significant disadvantage. This has been identified by the American Society of Engineering Education and ABET as problematic [3].

Why Combine ETE Capstones?

What are the benefits of combining ETE programs in the capstone? The capstone course(s) is the final academic culmination that allows students to integrate and apply their knowledge in support of a project that is representative of what they might encounter in the professional workplace [4 – 6]. As such, a combined course would be more representative of industry.

Engineering technologists/technicians are equally important in the design and development process, since they manufacture and support the end-product. Design is more than the technical design of the product, but includes the design of the manufacturing, documentation, and deployment processes as well. This is often defined as Integrated Product and Process Development (IPPD) [7].

Combining the two disciplines in the university capstone environment provides a significant benefit to the learning experience of students in both ETE disciplines as well as providing a better-rounded and better prepared entry-level employee for the workplace. It enhances the capstone experience, and better replicates the engineering workplace. Finally, it supports ABET student outcomes for both engineering and engineering technology while focusing on the professional skills development of the students [1 , 2].

ETE in Academia

The uniqueness of this capstone proposal lies in its combination of engineering and engineering technology disciplines. This necessitates further discussion on the similarities and differences between the disciplines.

The discussion of engineering "versus" engineering technology has emerged recently, especially in the current environment of highly multi-disciplinary projects, solving complex problems, and requiring advanced manufacturing capabilities [8]. The word "versus" is used appropriately, because the trend still exists in industry today [9]. Many engineering students are not exposed to engineering technology programs while in school. Indeed, this paper presents a cursory review of several institutions, and none of the top research institutions had colleges with both disciplines combined.

The difference between the two ETE programs of study stems from the famous Grintner report of 1955 [10]. This report from the American Society of Engineering Education charted the trajectory of engineering education as it has been defined for the past 61 years. Prior to 1955, engineering was considered an art, and practical application courses were integral to this curriculum. As the Cold War technology races began, the Grintner report charted a new curriculum with emphasis on math and science, an engineering core of subjects, highly educated faculty, and research. This current model is undoubtedly very familiar to academia today. Engineering Technology curricula arose in the 1960s to recover the practical and applied applications lost as a result of the Grintner initiatives [8].

The question then becomes "What is the difference between engineering and engineering technology?" The answer is presented in Table 1, which is drawn from several sources, but most notably (almost verbatim) from [11].

Table 1: ETE curricular differences

<table>
<tr><th>Program Characteristics</th><th>Engineering</th><th>Engineering Technology</th></tr>
<tr><td>Technical Courses</td><td>Stress the underlying theory and analysis techniques, as well as current and potential design applications</td><td>Stress application of current engineering knowledge and design methods in the solution of engineering, business, and industrial problems</td></tr>
<tr><td>Laboratory Courses</td><td colspan="2">Laboratory courses are a significant and integral component of both programs. They are designed to develop student competence in the application of experimental methods and to provide the physical bridge between physical principles and theories and the actual complexities and behavior of solid, fluid, and thermal systems.</td></tr>
<tr><td rowspan="2">Design Courses</td><td>Emphasis on general design principles and analysis tools applicable to a wide variety of emerging or break-through problem solutions</td><td>Emphasis on the application of design standards and procedures to complex contemporary problems</td></tr>
<tr><td colspan="2">Both focus on hands-on design experiences using real world industry problems and sometimes student design competitions. Although almost all design work is done in teams in both programs, more special opportunities can exist in engineering programs for independent research-based design/development studies.</td></tr>
<tr><td>Program Fundamentals</td><td>Require integral and differential calculus, multivariable calculus, and differential equations as well as basic science courses.</td><td>Require integral and differential calculus, as well as appropriate depth in the basic sciences.</td></tr>
</table>

ETE Review

In order to get a sense of other universities' approaches to ETE curricular programming, a review was conducted using the online academic websites of several universities across the United States. The first group consisted of the top-ten aerospace / aeronautical / astronautical engineering graduate schools, as ranked by *U.S. News and World Report*. The second grouping consisted of six universities that the authors' university considers to be peer institutions, as well as the authors' university itself. The third group contained five universities that university leadership considers to be aspirational institutions for certain areas of distinction. The last group consisted of a survey of the public institutions within the state of Ohio. A total of 32 institutions were examined.

Table 2 lists these institutions by grouping. It also provides the current ranking of the institution. Rather than list the university by name, the institutions are listed by rank and state. The top-ten ranking is specific to the aerospace disciplines. Other rankings are provided by *U.S. News and World Report* for the university as a whole. If the university has a Tier 1 ranking, the rank is provided. Otherwise, the university is ranked as Tier 2, since the numerical ranking is not published online. Some institutions have the same ranking.

Table 2 also specifies whether the institution has an engineering program or an engineering technology program. An asterisk appears by the name of the institution if both ETE programs exist, but are housed in different colleges or other units. The programmatic information was obtained by reviewing each institution's academic websites. These website reviews were conducted between April 5 and April 7, 2016.

Table 2: ETE institutional review

Top Aerospace Engineering Schools – *US News and World Report* [12]			
2016 Rank	**State of Institution**	**Engineering**	**Eng Tech**
1	Massachusetts	▪	
2	Georgia	▪	
2	California	▪	
4	California	▪	
4	Michigan	▪	
6	Indiana*	▪	▪
7	Texas	▪	
8	Colorado	▪	
8	Illinois	▪	
10	Texas*	▪	▪
10	Maryland	▪	

Peer Institutions and Authors' University			
2016 Rank	**State of Institution**	**Engineering**	**Eng Tech**
135	Ohio	▪	▪
175	**Ohio – Authors' university**	▪	▪
187	Texas*	▪	▪
187	Michigan		▪
Tier 2	Georgia		
Tier 2	Texas	▪	▪
Tier 2	Utah	▪	

Aspirational Institutions			
2016 Rank	**State of Institution**	**Engineering**	**Eng Tech**
47	Pennsylvania*	▪	▪
61	South Carolina	▪	
115	Pennsylvania	▪	▪

156	Florida	▪	
156	Virginia	▪	

Ohio public institutions (minus Ohio universities listed above))			
2016 Rank	**State of Institution**	**Engineering**	**Eng Tech**
52	Ohio	▪	
82	Ohio*	▪	▪
140	Ohio	▪	▪
185	Ohio		▪
Tier 2	Ohio	▪	▪
Tier 2	Ohio*	▪	▪
Tier 2	Ohio	▪	▪
Tier 2	Ohio	▪	
Tier 2	Ohio	▪	▪

*Programs not within the same college / unit.

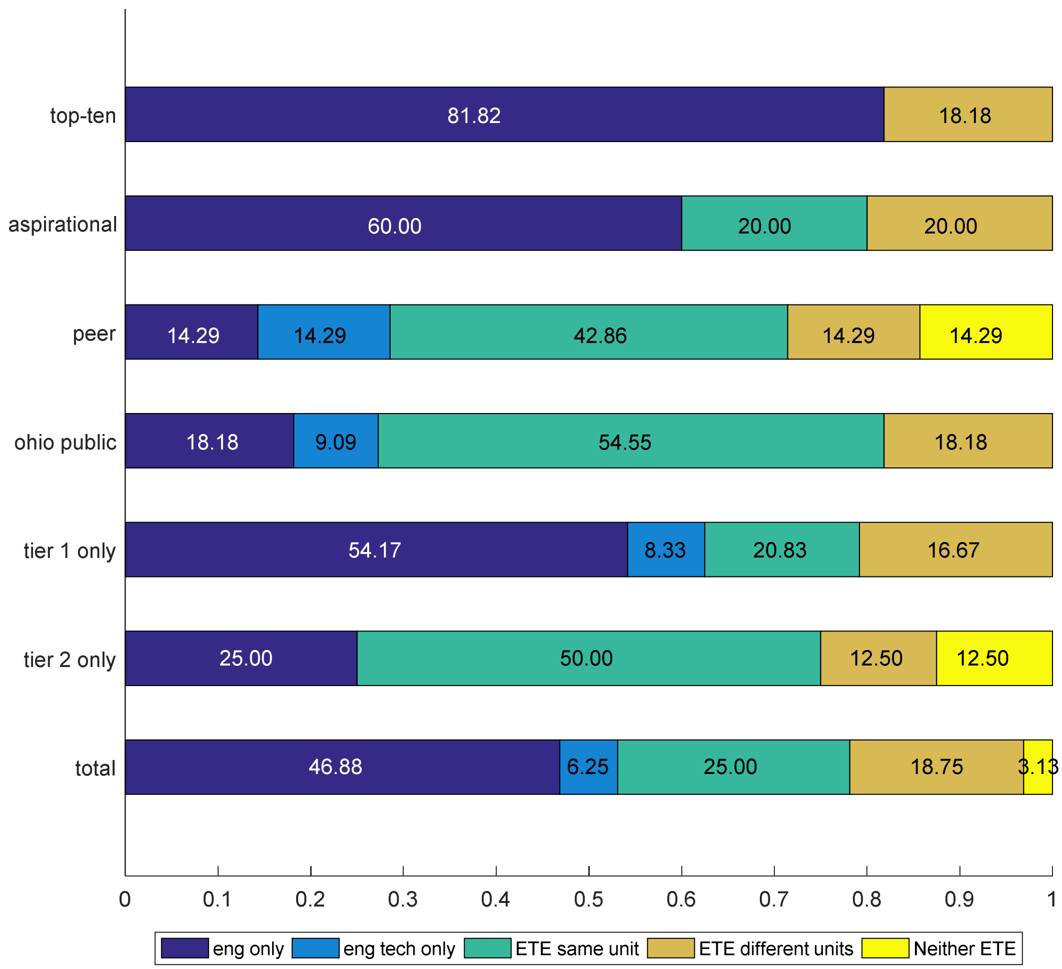

Figure 1: ETE institutional review results

The results of this review are interesting and highlight a potentially missed opportunity between the ETE disciplines in academia. The top-ten schools are almost exclusively engineering with no curricular mix of engineering and engineering technology. Those institutions rated as Tier One or as aspirational contain a similar mix, heavy on engineering only. The Ohio public and peer institutions almost mirror each other in the first four categories. This makes sense intuitively since Ohio is a state in the industry-heavy Midwest and Rust-Belt region. Peer institutions would also be expected to have several equal programs. One additional note is that these also align well with the Tier Two institutions.

Out of the 32 total institutions considered, almost 50% are exclusively engineering. Only 25% of the total have ETE programs in the same unit. The other 25% either do not have such ETE programs, only have an engineering technology program, or the ETE programs are housed in different units. In all cases, the authors could not find any evidence linking the capstone courses of the engineering and engineering technology programs at their respective institutions. Some ETE programs did, however, share lower-level courses.

The reader should also note how as the perceived rankings get higher (top-ten, aspirational, Tier One), the percentage of ETE programs decreases. Those units with a larger mixture of ETE programs tend to be lower ranked. This would seem to substantiate the perceived bias between disciplines and reinforce the notion that they should remain separate.

As presented in Figure 1, the lack of interaction between these two disciplines at the collegiate level is problematic. First, it reinforces a bias against engineering technology graduates. Second, these two disciplines are synergistic. Both are required to design, develop, produce, and support new technology. Third, the lack of interaction does not provide exposure of each discipline to the other prior to entering industry. This is a key component of the workplace environment that in most cases is completely missing from the academic experience.

ETE in the Profession of Engineering

In 2010, a survey of 200 engineering companies revealed that greater than 80% of them hire engineering technology graduates to occupy engineering positions not defined as senior, design, or research. When including those higher-level positions, over 60% of the companies surveyed used engineering technologists to fill those positions as well. Approximately 67% of the companies surveyed saw no significant distinctions between assigning roles and responsibilities based upon the degree obtained. When asked about significant differences between the capabilities of engineers and engineering technologists, 70% of the respondents saw little-to-no distinction between the two [8].

Figure 2 provides a good example of the synergy between the two ETE paths. It provides a list of the “engineering” career functions [11]. The figure highlights those functions typically completed by engineers and those typically executed by engineering technologists.

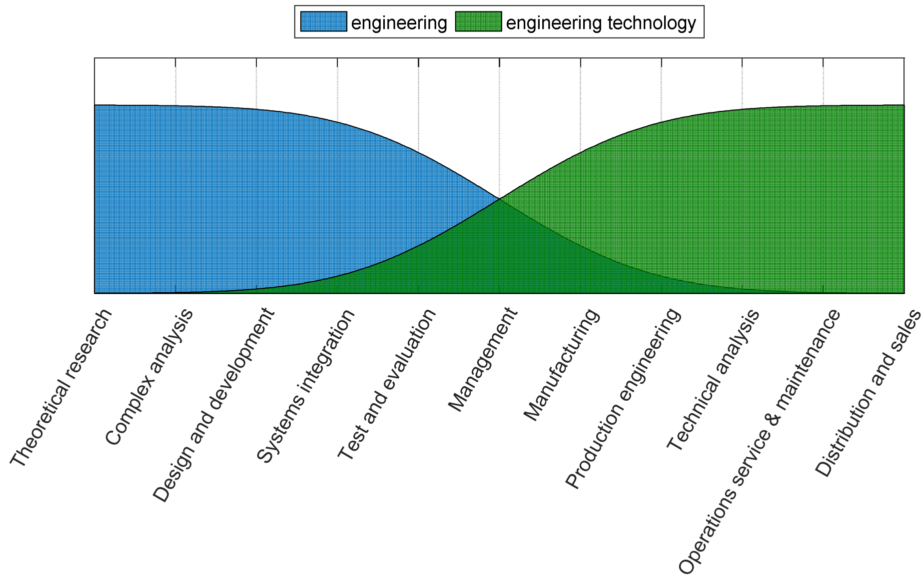

Figure 2: Engineering career functions

Capstone Requirements and Structure

The literature is full of papers discussing almost every aspect of a capstone design experience. According to recent studies in the literature, approximately 71% of the engineering capstone courses in the United States include some form of industry-sponsored project [4], [13]. Some capstones use projects which tend to be more altruistic in nature or to support communities in need or disadvantaged populations [14]. Some are design builds such as the AIAA design, build, and fly, the American Helicopter Society student design, or the SAE Mini-Baja competitions [15 – 17].

The literature and ABET have defined the typical characteristics of the capstone experience. According to Dutson, the design should be (1) challenging, (2) able to be completed in the allotted time, (3) require a knowledge of the state-of-the-art and the application of theory, while (4) meeting certain standards or criteria [18].

From [19], the course content of the design course(s) should include the following: (1) Identifying the need, (2) generating solution concepts and measures to evaluate them, (3) literature review and documentation, (4) prototyping of concepts, (5) identifying the key features of the design implementation, (6) communicating the solution and decision-making process, and (7) project management.

In design pedagogy, the general trends of capstone design courses have changed significantly [20, 21]. Courses now tend to run the course and project in parallel as well as provide a lab section for students to work on the project. The duration of the capstone has extended in most cases to encompass a complete academic year. The number of students on a design team has trended smaller. The designs themselves are typically smaller and based upon industry associations. Lastly, the priority of topics has also shifted away from oral and written communication and more toward ethics and project management.

Combined Aerospace Capstone Sequence

The aircraft design capstone is different in many respects. First, an aircraft is designed differently from other systems. There is a “backward” nature to the design, because of the sensitivity of the weight of the aircraft to performance parameters [22]. Aircraft weight affects all aspects of the design.

Aircraft are a complex system of systems that must work together, with potentially life-threatening consequences to a large number of people at once [23]. The design process is highly iterative from initial concept to final design. This process is normally measured in years.

Aircraft must undergo more rigid requirements than almost anything else. The system includes the aircraft, training and support equipment, facilities, and personnel [23]. For example, one can learn how to operate an automobile and obtain a driver license at very little cost. Becoming a commercial multi-engine rated pilot instructor can cost up to $100,000 in an aeronautics program at a university, plus additional expense to become an airline transport pilot. Aircraft and maintenance programs must be certified as airworthy. Aircraft must meet rigid federal aviation regulations or military specifications. These designs become necessarily more complex and involved at every level.

The aircraft design course sequence combines the following objectives in curriculum design:

1. Merging engineering and engineering technology fields of study
2. Merging technical and non-technical aspects of aircraft design
3. Emphasizing project management and structure
4. Incorporating 3D prototyping technology for the fabrication and evaluation of a design prototype
5. Incorporating real engine data from a high-bypass turbofan virtual engine bench

1. Merging ETE fields of study

This paper has already discussed the lack of synergy between ETE at the collegiate level. In merging these fields of study, a project-based design course sequence exposes students in both disciplines to the related, yet different aspects of both fields of study.

One of the authors has taken and taught several aircraft design courses at different institutions at both the graduate and undergraduate levels, in both engineering and engineering technology. As such, the author has personally observed the difference in focus between the two disciplines. Engineering students are much more focused on the engineering parameters of the aircraft to meet system requirements. Engineering technology students focus on the specifics of the systems to be used in the aircraft itself – fuel, environmental, hydraulic, etc. Engineers seem to take longer to get started and need more guidance during the process than engineering technology students. This latter observation has also been observed in industry [8].

2. Merging technical and non-technical aspects of aircraft design

While the technical aspects of aircraft design are important, non-technical aspects play a vital role in the development, production, and marketing of a new aircraft as well. Some of these non-technical aspects are presented in Table 3 below. Given that some of these less technical aspects are within the spectrum of career functions encountered by engineering technology graduates, it makes sense to perform a more in-depth investigation to better replicate the workplace environment. This provides the multi-disciplinary aspect.

Table 3: Some non-technical aspects of product design

Stakeholders / Customers	Program Management	Finance
Manufacturing	Integrated Product Team	Legal & Regulatory / Safety
Value Proposition / Marketing	Communication	Sales & Distribution
Socioeconomic Impacts / Ethical Considerations		

3. Emphasizing program management and structure

In many cases, the capstone course is one of the only academic opportunities for students to serve on a large team, oriented toward a common goal. Failure to function effectively as a team often has significant academic repercussions. Additionally, the constricted timeline of academic coursework further serves to illustrate the importance of forming a project team quickly and establishing a realistic schedule to meet the requirements by the end of the semester(s). One of the primary goals of this work is to formulate a project-based template to guide the students in managing their work schedule, milestones, and deliverables.

This course also strives to further develop the "professional skills" so often mentioned by industry and ABET as lacking in college graduates (effective communications skills, teamwork skills, etc.). From [24], these attributes / professional skills indicating the quality of an engineer are (1) motivation, (2) technical competence, (3) judgment and decision-making, (4) innovation, (5) client/quality focus, (6) business orientation, (7) product development, (8) professional / ethical, (9) teamwork, (10) change management, and (11) communication. These are especially important since both engineers and engineering technologists perform the management career function, as was depicted in Figure 2.

4. Incorporating 3D prototyping technology for the fabrication and evaluation of design prototype

With the rapid proliferation of additive manufacturing, it is expected that the design teams will produce a three-dimensional prototype of their design for evaluation, analysis, and presentation using 3D printing or other means. It is further expected that the students will eventually use these prototypes to evaluate preliminary aircraft characteristics by experimental means (i.e., aerodynamic characterization through wind tunnel experimentation). An example prototype is depicted in Figure 4. Again, using emerging prototyping tools is an opportunity relevant to both ETE disciplines.

Figure 3: Example aircraft design prototype

5. Incorporating real engine data from a high-bypass turbofan virtual engine bench

In 2015, the college procured a virtual engine bench by Price Induction (Figure 4). The test bench offers a unique pedagogical and multi-disciplinary tool for illustrating the behavior and performance of a turbofan engine and providing a platform for practical laboratory coursework and instruction. The virtual test bench replicates the DGEN-380 turbofan engine, a turbofan optimized for general aviation and operation below 25,000 feet. The bench uses an electronic block to simulate engine operation, consisting of the virtual engine, a full authority digital engine control (FADEC) microcontroller, and debug interface. This engine serves as the powerplant for the design. The bench also provides information to estimate aircraft performance parameters. This technology becomes very useful for sizing the aircraft and estimating its performance.

Figure 4: Virtual engine test bench

This is not to say that the capstone would always revolve around this powerplant. The use of this engine provides a manageable design project, using available technology to extract meaningful data. In subsequent offerings of the course, other types of aircraft could certainly be considered.

Table 4 provides a list of the topics to be covered during the capstone sequence. The fall semester begins with an introduction to the design process and ends with completion of the aircraft's preliminary design. The spring semester delves into the step-by-step development activities and then branches more into the non-technical aspects. Both semesters end with final reports and presentations

Table 4: Capstone design topics

Fall Semester Topics	Spring Semester Topics
Introduction to the Design Process	Step-by-step development activities
The ETE disciplines	• Aerodynamics
Professional/Ethical Awareness	• Propulsion
Team Behavior / Group Dynamics	• Stability and Control
Project Management	• Structure
Problem Definition & Need Identification	• Systems
Preliminary Design	Design for Manufacturing
• Mission profile	Risk, Reliability, & Safety Management
• Initial Sizing	• Certification Requirements
• Geometry	• Failure Analysis
• Response surfaces	Business Development Activities
Communication	• Value Proposition
• Preliminary Design Review	• Economic Analysis
• Final Report	• Marketing Strategies
Site visit to Industry	Prototyping activities
	Optimization studies
	Communication
	• Final Design Review
	• Technical Paper

Impact and results

The course sequence contributes significantly to the engineering and engineering technology programs at the authors' university. This is a unique curricular opportunity, centered around a very applied, project-based learning experience, adhering closely with evolving engineering education pedagogy. The outcomes of this course directly link to *all* of the current student outcomes in the ABET criteria for both engineering and engineering technology fields of study. These outcomes are highlighted in Table 5

Table 5: ABET student outcomes

Engineering student outcomes* [1]	**Engineering technology student outcomes** [2]
An ability to apply knowledge of mathematics, science, and engineering	An ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities
An ability to design and conduct experiments, as well as to analyze and interpret data	An ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies
An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	An ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes
An ability to function on multidisciplinary teams	An ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives
An ability to identify, formulate, and solve engineering problems	An ability to function effectively as a member or leader on a technical team
An understanding of professional and ethical responsibility	An ability to identify, analyze, and solve broadly-defined engineering technology problems
An ability to communicate effectively	An ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature
The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context	An understanding of the need for and an ability to engage in self-directed continuing professional development
A recognition of the need for and ability to engage in lifelong learning	An understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity
A knowledge of contemporary issues	A knowledge of the impact of engineering technology solutions in a societal and global context
An ability to use the techniques, skills, and modern engineering tools necessary for	A commitment to quality, timeliness, and continuous improvement

engineering practice	

*The authors are aware of the current proposals for substantive change to the ABET criteria. When approved, the courses will link accordingly.

This capstone is still in its implementation and evaluation phase and will require 3-4 iterations to assess the effectiveness of the sequence proposed here. To date, the aeronautical systems engineering technology capstone has implemented 4 of the 5 design sequence objectives. Due to the newness of the university's aerospace engineering program, a cohort class has yet to progress to the senior level yet. The current capstone course has integrated the other four objectives during the past three course iterations with positive results. As the first aerospace engineering classes fully matriculate, the success of the sequence will be better understood.

Another important note is that these concepts work due to the nature of the aerospace capstone, which centers around the design of an aircraft or spacecraft, which is a complex system with life-altering implications. These are similar to other systems on the level of ship, power plant / power grid, or building design of other engineering disciplines such as marine, mechanical, nuclear, or civil engineering, etc. For other capstones, it is unclear how successful a merging of ETE students would be for smaller design projects. It may very well be that such a merge would be problematic in other instances.

Conclusion

This paper has summarized the development and implementation of an aerospace capstone sequence for both engineering and engineering technology students through the following:

- highlighting the importance of both engineering and engineering technology programs to the profession of engineering.
- highlighting the curricular differences between the two disciplines
- highlighting the current lack of synergy between ETE curricula through a review of 32 institutions across the United States.
- highlighting the indistinguishability of graduates of either program of many engineering companies
- highlighting some of the intrinsic differences between aerospace designs and other designs and the necessity of a more robust capstone experience
- highlighting the capstone design objectives and lesson topics

The implementation of this sequence is still in progress, but in developing an aerospace capstone that combines engineering and engineering technology, the institution not only provides an experience for students that better replicate the multi-disciplinary workplace environment, but it also addresses the aforementioned concerns highlighted by industry [8].

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References

[1] "2015-2016 Criteria for Accrediting Engineering Programs," 2015. [Online]. Available: http://www.abet.org/accreditation-criteria-policies-documents/. [Accessed: 01-Jan-2016].
[2] "2015-2016 Criteria for Accrediting Engineering Technology Programs," 2015. [Online]. Available: http://www.abet.org/accreditation-criteria-policies-documents/. [Accessed: 01-Jan-2016].
[3] National Engineering Education Research Colloquies, "The Research Agenda for the New Discipline of Engineering Education," *J. Eng. Educ.*, no. October, pp. 259–261, 2006.
[4] J. R. Goldberg, G. Corliss, K. Kaiser, J. A. Y. Goldberg, V. Cariapa, G. Corliss, and K. Kaiser, "Benefits of Industry Involvement in Multidisciplinary Capstone Design Courses," vol. 30, no. 1, pp. 6–13, 2014.
[5] H. F. Hoffman, *The Engineering Capstone Course*. 2014.
[6] B. D. Jones, V. Tech, C. M. Epler, V. Tech, and L. H. Bryant, "The Effects of a Collaborative Problem-based Learning Experience on Students ' Motivation in Engineering Capstone Courses," vol. 7, no. 2, pp. 5–16, 2013.
[7] Dieter and Schmidt, *Engineering Design*, 5th ed. McGraw-Hill, 2013.
[8] R. E. Land, "Engineering technologists are engineers," *J. Eng. Technol.*, vol. 29, no. 1, p. 32, 2012.
[9] M. Lord, M. and Matthews, "R-E-S-P-E-C-T, Engineering Technology Steps Up to TCB in the Advanced, Manufacturing Era," *Prism Magazine*, pp. 24–34, 2015.
[10] L. E. Grinter, "Summary of the Report on Evaluation of Engineering Education," *J. Eng. Educ.*, vol. 46, no. January, pp. 25–60, 1955.
[11] ASME, "Pathways to Careers in Mechanical Engineering: Program Characteristics," 2015. [Online]. Available: https://www.asme.org/career-education/k-12-students/pathways-careers-in-mechanical-engineering/program-characteristics. [Accessed: 03-Oct-2015].
[12] "Aerospace / Aeronautical / Astronautical Engineering, Ranked in 2016," *U.S. News and World Report*, 2016. [Online]. Available: http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-engineering-schools/aerospace-rankings. [Accessed: 05-Apr-2016].
[13] S. Howe, "Where are we now? Statistics on capstone courses nationwide," *Adv. Eng. Educ.*, vol. 2, no. 1, pp. 1–27, 2010.
[14] R. E. Anderson, R. J. Anderson, G. Borriello, and B. Kolko, "Designing Technology for Resource-Constrained Environments : Three Approaches to a Multidisciplinary Capstone Sequence," 2012.
[15] "AIAA Student Design / Build / Fly Competition," 2016. [Online]. Available: http://www.aiaadbf.org/. [Accessed: 25-Apr-2016].

[16] "AHS Student Design Competition," *2016*. [Online]. Available: https://vtol.org/education/student-design-competition. [Accessed: 25-Apr-2016].
[17] "SAE Collegiate Design Series," 2016. [Online]. Available: http://students.sae.org/cds/. [Accessed: 25-Apr-2016].
[18] A. J. Dutson, R. H. Todd, S. P. Magleby, and C. D. Sorensen, "A review of literature on teaching engineering design through project-oriented capstone courses," *J. Eng. Educ.*, vol. 86, no. January, pp. 17–28, 1997.
[19] A. J. Mcgoron, H. Shahrestani, M. E. Brown, and J. D. Byrne, "Delivery and Assessment of the Biomedical Engineering Capstone Senior Design Experience," in *120th ASEE Annual Conference & Exposition*, 2013.
[20] J. Pembridge and M. Paretti, "AC 2010-811 : The Current State of Capstone Design Pedagogy," *Am. Soc. Eng. Educ. Annu. Conf. Expo.*, 2010.
[21] J. Wilbarger and S. Howe, "Current practices in engineering capstone education: Further results from a 2005 nationwide survey," in *Proceedings - Frontiers in Education Conference, FIE*, 2006, pp. 5–10.
[22] D. P. Raymer, *Aircraft Design: A Conceptual Approach*, 5th ed. AIAA (American Institute of Aeronautics & Astronautics), 2012.
[23] M. S. Jackson, *Systems Engineering for Commercial Aircraft: A Domain-specific Adaptation*. Ashgate Publishing, Ltd., 2015.
[24] D. Davis, S. Beyerlein, P. Thompson, K. Gentili, and L. McKenzie, "How Universal are Capstone Design Course Outcomes?," *2003 ASEE Annu. Conf. Expo. Stay. Tune with Eng. Educ.*, 2003.

Biographies

D. BLAKE STRINGER is currently an assistant professor of aeronautics at Kent State University. Prior to joining the faculty at Kent State, Dr. Stringer served in the Army for 20 years as an army aviator, West Point faculty member, and research engineer. He holds a bachelor's degree in aerospace engineering from the US Military Academy, a master's degree in aerospace engineering from Georgia Tech, and a doctorate in mechanical and aerospace engineering from the University of Virginia. His research interests include unmanned aerial systems, the aerodynamics and performance of vertical axis wind turbines, rotating mechanical components, and engineering education pedagogy.

MAUREEN MCFARLAND is currently the Aeronautics Senior Program Director and an assistant professor at Kent State University. Prior to joining the faculty at Kent State, Prof. McFarland served in the Marine Corps as a navigator at which time she transitioned to the Marine Corps Reserve, retiring after 20 years of service. She holds a bachelor's degree in aerospace engineering from the US Naval Academy, a master's degree in business from Boston University, and is a doctoral candidate in educational psychology at Kent State University. Her research interests include assessment, effective teaching practices using instructional technology, and engineering education pedagogy.